Eucalyptus based agro forestry systems for improving the productivity of arable lands

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1. Introduction:
In India, vast areas forested land has turned bare as a result of indiscriminate felling and exploitation. The problem has arisen when demand far exceeded the capacity of forest to supply wood without damage to the natural balance. It is not only the large forests that have been affected, small groves near villages, which helped meet needs of firewood and fodder, too have vanished. A growing rural population with limited income opportunities and the related widespread rural poverty due to shrinking resource base have led to encroachment of forestlands. Diversion of forestland to non-forest uses (of the order of 150,000 ha. annually) has also led to large-scale destruction of forests. It is estimated that of the 130 million ha of barren land in the country, 70 - 80 million ha. is under private ownership. Such lands when developed carefully with various site-specific tree species for fodder, firewood, pulp and timber for various industries will return the green cover and can help change the picture completely in a few years.

2. Agroforestry; a Sustainable land use:
Agroforestry is an age-old practice. Trees and shrubs are important in the traditional farming systems of the tropics, where woody species form a major component of the bush fallow system and are also widely grown in cropped land. Trees and shrubs benefit the farmer in three main areas:

- Direct agricultural benefits (plant stakes, mulching materials, green manure, animal fodder and so on);
- Environmental benefits (shade, soil erosion control, nutrient recycling, carbon sequestration and so on);
- Socioeconomic benefits (saleable commodities like timber, fruits, vegetables, cereals, building materials, and so on).

In agroforestry land use systems, trees and woody shrubs grow together simultaneously or sequentially with agricultural crops and/or pasture and livestock. An economic and ecological interaction exists between the tree and non-tree components of the system. Agroforestry has not only benefit farmers, it also supplies raw material to wood industry, generate employment of various kinds thus benefiting millions in related economic activities like transportation, wholesale, retailing etc. It help consumers with an affordable supply of wood and contributes to import substitution for timber and timber related products, which India imports worth thousands of crores of rupees a year. Also, agroforestry is as good, if not better, than degraded forests for environmental improvement, pollution control, etc, especially as it can be initiated in farmers' holdings in villages and nearer to urban conglomerations. It is a win-win situation for all.

Agroforestry systems for pulpwood production thus consist of growing of "commercial timber trees for wood industry in agricultural fields" with irrigation, fertilizers, plant management technology, etc., in a harvest cycle of 4 - 7 years. Crops growing underneath form a small part of the gross income. Selective shade-loving or shade-tolerant crops are grown to complement timber production and cash flow.

As the trees have to be grown on a quick rotation, the species selected should not only be fast growing, but also suitable for combing with agriculture to maintain regular returns for farmers till harvest of the trees. Diversification of agriculture should receive very high priority as water resources are depleting and we are unable to arrange proper storage and distribution of huge stocks of food grains. However, tangible results can be achieved only if farmers are offered practical, viable and economically attractive alternative land use options. Technology based farm-forestry plantations with genetically improved, high yielding and fast growing clonal planting stock of species like Eucalypts have tremendous potential for diversification of agriculture and meeting growing shortages of industrial timber on sustainable basis

3.Eucalyptus as an agroforestry tree species:

The *Eucalyptus* L'Herit...Native of Australia is the second dominant hardwood planted species after *Pines* in an area of 10 to 15 million ha throughout the world (Neilson 2000). It is estimated that there will be more than 20 million ha of eucalypt plantations outside Australia by the year 2010 (Doughty and Doughty-2000). Most of the myths associated with *Eucalyptus* like depletion of under ground water resources, deterioration of soils and allelopathic effects on agricultural crops are not based on scientific facts. On the contrary, soil and water resources are better conserved under any trees including *Eucalyptus* compared to keeping large tracts of land barren or even under grass cover. The study showed that *Eucalyptus* consumed 0.48 liters of water to produce a gram of wood, compared to 0.55, 0.77, 0.50 and 0.88 liter per gram for *Siris, Shisham, Jamun* and *Pongamia* respectively (Prabhakar, 1998). Chaturvedi *et al* (1988) reported that of ten species tested for water consumption, *E. tereticornis* was found to be the most efficient in biomass production per liter of water consumed.

Demand for nutrients by *Eucalyptus* is less than others, principally because heartwood begins to form at approximately four years. After this point, a significant proportion of nutrients in wood is recycled to other parts of the tree or soil, and the quantities that are immobilized are kept to a minimum. *Eucalyptus* also contributes to the intense deposition of organic matter on the soil - through leaves, bark and roots - estimated at seven tones per hectare per year (Carpanezzi 1980, Poggiani 1985, Lima 1987), thus contributing to the soil fertility improvement.

Eucalyptus is one of the trees can be grown with crops. *Eucalyptus* is the most popular choice to be planted along the edges, or bunds, of agricultural fields, and appears to be well incorporated and accepted in agro-forestry in India (Tejwani, 1994). Silvicultural properties including straightness, narrow crown, self-pruning, high growth rates, adaptability to a wide range of soils and climates, coppicing ability, a tendency not to spread as a weed and wide utility of wood are some of the main features of *Eucalyptus* Clones making it popular among the farmers for raising as block plantations. *Eucalyptus* has more than 600 species, among

which two species, *Eucalyptus camaldulensis* Dehnh and *E. tereticornis* Smith are cultivated more among the farming community in Andhra Pradesh, as being sufficiently drought tolerant while also capable of withstanding, under irrigation and saturation, very hot summer temperatures and suitable for a wide range of sites. The species were, of course, also selected because they are suitable for the manufacturing of quality paper.

4. Role of Private Sector in Promotion of agro forestry and farm forestry:

In agroforestry or farm forestry programs where intensive cropping of forest species is undertaken, vegetative propagation of desired clones assumes still greater economic importance. Great benefits have accrued from clonal selection and breeding of Eucalypts and from more intensive management practices, in which Private sector has led the way in India. Fast growing, high yielding and disease resistant clones of *Eucalyptus* popularly called as "Bhadrachalam Clones" has a productivity of is 3 to 4 times higher compared to the productivity of normal seed based plantations (Lal, 2000). Clonal *Eucalyptus* plantations, promoted, are the first successful example in India of commercial scale clonal plantations of any forestry species traditionally propagated through seedlings.

Agro forestry and farm forestry promoted by Private sector Limited with clonal *Eucalyptus* plantations benefited thousands of farmers who planted 8 million ha. during 1992 to 2007. Year by year there is an increasing trend in plantation area and number of farmers taking up plantations which clearly shows the popularity of Eucalyptus Clones among farmers which is illustrated in **Chart 1**.

Methodology adopted for development and commercial scale deployment of high yielding and disease resistant clones of *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* has been as follows:

- Selection of candidate plus trees (CPTs), with most desirable phenotypic qualities like high volume, large clear and cylindrical bole, dominant height and disease resistance, etc.

- Clonal multiplication of CPTs through rooting of leafy stem cuttings from 50 to 60 days old juvenile coppice shoots treated with 6000 parts per million Indole Butyric Acid, under controlled environment in the green houses.

- Evaluation of comparative genetic superiority of resultant clones through replicated field trials and selection of genetically superior high yielding and disease resistant clones for commercial multiplication.

- Trials for Genotype x Environment interaction studies were carried out to identify specific groups of genetically superior clones most adaptable to problematic sites such as alkaline and calcareous black cotton soils.

Eucalyptus plantations promoted by the private companies receive generous incentives such as technical know-how for establishing the trees on the farmer's land and contracts with

the farmer to buy some or all of the first harvest for an agreed upon price at the time of harvesting, sales tax exemptions on the pulp wood, procurement though Agricultural Market Committees, no middle man involvement hence farmer can sell his produces directly to the end users and various tax holidays and tax exemptions for extended periods apart from element of subsidies on the *Eucalyptus* clones given by the company. These incentives put *Eucalyptus* at an advantage compared to other agricultural crops (including perennials), which receive no such promotion.

5. Cultivation practices of Bhadrachalam Clones:

Apart from superior genetic quality of the planting stock, site quality of the land, adaptability of the clones to specific sites, implementation of improved package of practices and effective protection of plantations from damage by pests, diseases and cattle are important factors, which determine the overall productivity of the plantations. Therefore, the Company developed improved package of practices for raising and maintenance of clonal *Eucalyptus* plantations and demonstrated benefits of the same to the farmers. These plantations are harvested in 4 - 5 years cycle, one among the shortest maturity cycle in the world. Because the E*ucalyptus* tree coppices after felling, it is possible to obtain more than one harvest from a single tree. Study of soil profiles and analysis of soil samples is carried out to match adaptable clones to the planting sites.

Deep ploughing of the soil with disk plough or mould-bold plough in both directions is recommended for preparing the fields for transplanting of clonal saplings. Spacing of 3 x 1.5 M is recommended for production of poles and pulpwood, and larger spacing is desirable for production of timber from clonal *Eucalyptus* plantations. Transplanting in 30 x 30 x 30 cms. pits is carried out after the onset of the monsoon rains so that plants establish and grow well benefiting from the good moisture availability throughout the monsoon rains. Soil in and around the planting pit is treated with 2 ml of Chloropyriphos in 1 liter of water to prevent damage to the young clonal saplings by termites during the critical establishment stage. Cultural practices recommended include timely weeding and soil working, protection against damage by insect pests and cattle and raising of leguminous or any shallow rooted crops in between the 3 meter wide planting rows. As *Eucalyptus* is heavy feeder of nutrients like N, P, K and Ca and most of the soils in India are deficient in nitrogen and phosphorus, application of fertilizers to supplement availability of these deficient plant nutrients is recommended. Based on the soil test reports application of Potassium and Calcium also has to be given as per requirement. Soil and water conservation measures like raised field boundaries and staggered trenches are recommended in well-drained planting sites for holding the rainwater.

For block plantation the distance between the trees 3 meters and with in rows 1.5 meters which hold 2222 plants per hectare and allows raising of intercrops in first two years in the cycle of 4 yr. rotation period. Intercrops such as Chilies, Cotton, Tobacco, Black gram, Green gram are widely grown with *Eucalyptus* during the initial years.

6. Biomass production of clones:

Eucalyptus plants have a lot of variation that results into lower biomass productivity. It has been found that in seedling plantations, 67 per cent inferior trees produce 33 per cent of the total volume, while 33 per cent superior trees contribute 67 per cent of the volume. A population of genetically identical individuals that are obtained through vegetative propagation is known as a clone. These clonal plants have higher productivity due to better genetic quality and uniformity. In Congo, Brazil and Papua New Guinea, clonal plantations of *Eucalyptus* have produced 70-90m3/ha/yr. The productivity of clonal plantations raised under rainfed conditions at Bhadrachalam has given yields varying from 20 to 44 m3/ha/yr compared to 6-10m3/ha/yr of seed route plantations. Comparative growth data of various clones, in one of the clonal testing area, is given in**.**

Major gains in productivity of *Eucalyptus* plantations have been achieved in a short time span of 15 years through applications of vegetative propagation and cloning techniques for gainful exploitation of existing useful variation. Development and commercial scale deployment of locality specific, high yielding, fast growing and disease resistant clones of *Eucalyptus*, traditionally propagated through seed, has been successfully achieved for the first time in India by the Company. The company released about 15 number of promising clones for commercial cultivation among which 4 clones occupy more than 50% of the total area. The productivity of clonal plantations raised under rainfed conditions has given yields varying from 20 to 44 m3/ha/yr compared to 6-10m3/ha/yr of seed route plantations (Lal and Kulkarni, 1992). However, many farmers have redefined productivity standards by achieving unprecedented record yield of 50 $m^3.ha^{-1}.yr^{-1}$ **(Table 2).**

7. Economics of *Eucalyptus* based agro forestry systems:

The combination of agricultural crops with *Eucalyptus* trees for pulpwood production can bring a higher profit than pure plantings of either. The profitability of *Eucalyptus* planting by individual farmers varies with the farm gate prices and yields of the trees, which in turn depend on the quality of the soil, the spacing, and the technology of production. The opportunity cost of the land is an important factor affecting the net return to the planters. Under the base case, we have used the net return of inter crops like Chilies, Cotton, Green gram, Black gram, Upland rice on land with fairly poor soil.

High yields combined with better quality of produce and lower per unit production costs have improved profitability of clonal *Eucalyptus* plantations substantially. Because of better soils, adequate irrigation facilities and more progressive farmers, productivity of clonal *Eucalyptus* plantations is likely to establish new records. Farmers can expect on an average net returns upto Rs.3, 00,000/ hectare at 4 years rotation from irrigated clonal *Eucalyptus* plantations assuming yield of 150 tones and current farm gate price of Rs.2000/ per tone for *Eucalyptus* logs. No wonder therefore that clonal farm forestry plantations of *Eucalyptus* are emerging as an attractive alternative land use option offering tremendous opportunities for diversification of agriculture.

8. Conclusions:

Based on cost structure, yields, and farm gate prices, it was found that larger-scale planters are likely to receive a higher profit than the smaller-scale planters. While large-scale planters make a healthy profit of Rs.75, 000 per year/ hectare, small-scale planters with low-cost credit from the agricultural banks, just break even. Our findings support the general belief that tree planting is usually a business for relatively wealthy farmers, who have large enough land holdings and the capital to diversify their farming activity and experiment with new crops. Small farmers find it difficult to adopt tree growing because of the tree's lengthy production period and the high initial establishment cost. The lack of capital and small land holdings make it difficult for small farmers to diversify their cropping patterns. Larger holdings, more farm assets, higher off-farm income, and access to low-cost credit allow larger planters a better chance to accept the risk of adopting new crops with a relatively long gestation. To over come the financial burden of small farmers they can adopt agroforestry models which allows growing of intercrops along with the trees crops which can fetch some immediate returns in the first two years.

As the Government of India has already launched a massive program of watershed development, linkage of agroforestry as an integral part of this program will not only provide an opportunity to enhance biomass production, but also improve the profitability. Through soil and water conservation, green manuring, agroforestry and integrated crop protection, the yields of inter crops can be substantially high, till the inter crops are affected by the shade. Such tree based farming systems have been highly effective in preventing migration of rural families and supporting livestock husbandry to enhance their income by 35-40%. Each hectare of clonal plantation with productivity of 20 Cum/ha/yr. can produce enough fuel wood and small timber to conserve 20 ha natural forests. Reforestation of degraded forest lands, devoid of tree cover, with high yielding clonal plantations can restore this timber of local communities. This will help minimizing biotic pressure on the natural forest and conserve the rich bio diversity.

Table 1. Clonal testing area 21, Location - Bhadrachalam
Growth Data of Clones under Testing. Age - 8 years.

Sl.No.	CLONE NO.	GBH cm	HT (Mt)	VOL/HA UB m3	CAI VOL/HA (UB,m3)	MAI VOL/HA (UB,m3)
1	288	58	21	334.1	55.9	41.8
2	6	60	20	321.0	40.3	40.1
3	286	57	20	313.2	40.9	39.1
4	284	54	20	278.3	35.2	34.8
5	285	54	19	262.2	28.8	32.8
6	277	53	17	234.2	25.2	29.3
7	275	51	19	235.1	28.0	29.4
8	3	50	19	227.9	26.0	28.5
9	274	47	19	204.0	23.3	25.5
10	269	49	17	193.0	21.8	24.1
11	276	49	18	188.9	15.5	23.6
12	271	47	18	185.3	22.8	23.2
13	283	46	17	164.1	31.9	20.5
14	268	47	17	165.3	19.0	20.7
15	270	41	16	130.1	8.3	16.3
16	SC	36	14	53.1	0.0	6.6

1. volume in cubic meters (without bark) calculated based Regression Equation V = 0.00258 + 0.0281 G^2H
2. Volume rounded off to one decimal point
3. Data arranged in descending order of MAI as per assessment.
4. Spacing 3 M x 2 M
5. No. of saplings planted per treatment 9 with 3 replications.
6. Species *Eucalyptus tereticornis* clone Nos. 3,6,268,270,271,274,268,275,276,277,283,284,285,286,288
7. Shortlisted promising 'Bhadrachalam' Clone Nos.: 288,286,285,277,275,274,271,269,276,268.
8. Soil type is red soil.
9. CAI = Current Annual Increment; MAI = Mean Annual Increment; D.O.P = Date of Planting;

   GBH = Girth at Breast Height; HT = Height; Vol. = Volume; HA = Hectare

Table 2. Productivity of Eucalyptus Clonal Plantations in Agroforestry

S.No	Name of the Farmers	Village	District	Age Mths.	Soil Type	IRR/RF	Clone No.	Survival %	Spacing (M)	Vol/HA (UB,CUM)	CAI	MAI
1.	Seshaiah	Lingamguntla	PKM	63	Sandy	IRR	10	96	3.0 x 1.5	217.76	38.96	41.48
2.	Sitaramaiah A	Gullapally	PKM	51	Black	RF	128	98	3.0 x 1.5	170.53	42.93	40.12
3.	Reddy D.CH	Nelaturu	PKM	50	Red	IRR	3	99	3.0 x 2.0	150.00	35.50	36.00
4.	Reddy D.CH	Varagani	GNT	53	B. Cotton	IRR	10,52,71	92	3.0 x 2.0	125.79	58.22	28.48
5.	Ranga Rao V	Yanamadala	GNT	41	Red	RF	3	67	3.0 x 2.0	145.51	60.11	42.59
6.	Sambasiva Rao P	Unnava	GNT	42	B. Cotton	IRR	3,6,7,128,130	96	3.0 x 1.5	134.47	77.81	38.42
7.	Venkata Reddy D	Nimmalagudem	WG	42	Sandy Loam	IRR	3	95	3.0 x 1.5	120.74	44.84	34.50
8.	Laxman Rao	Jangareddygudem	WG	48	Sandy	RF	3,7,10,27	98	3.0 x 1.5	129.21	54.56	32.30
9.	Koteswara Rao S	Pothuru	GNT	40	B.Cotton	RF	130,	83	3.0 x 2.0	133.23	98.23	39.79
10.	Koteswara Rao Ch	Palapadu	GNT	41	Red	IRR	130	52	3.0 x 2.0	161.04	107.44	47.13
11.	Balakrishna M	Veerabhadravaram	WG	24	Red	IRR	3,10	98	3.0 x 1.5	83.79	31.84	41.86
12.	Ramakrishna T	Bitragunta	NLR	27	Red	RF	3,	52	3.0 x 1.5	71.41	21.31	31.74
13.	Raghava Reddy G	Lingampalli	NLR	27	Red	IRR	10	98	3.0 x 1.5	64.83	30.63	28.81
14.	Mohan Reddy	Leguntapadu	NLR	22	Black	RF	3,7,130	100	3.0 x 1.5	54.16	36.20	29.54
15.	Srilakshmi Ch	Tenamadala	GNT	15	Red	IRR	105,130	99	3.0 x 2.0	32.53	32.53	26.02
16.	Krishnaveni K	Santavelluru	NLR	12	Red	IRR	3,10,130	99	3.0 x 1.5	30.83	30.83	30.83
17.	Madhusudhan Rao Ch	Nellipaka	KMM	27	B.Cotton	IRR	3,10,130	94	3.0 x 2.5	52.33	30.53	23.26
18.	Ramaraju G	Pochavaram	KMM	40	B.Cotton	RF	128,3,7,15,8	99	3.0 x 2.0	100.47	44.72	30.14
19	Butchiramaiah MV	Nandigama	KMM	64	B.Cotton	RF	6,10,3,8	87	3.0 x 2.0	168.83	70.68	31.66
20.	Chandrasekhara Rao TV	Venkatareddypeta	KMM	40	Alluvial	RF	128,116,3,6,7,130	98	3.0 x 2.5	103.18	63.72	30.96
21.	Bhaskar Rao T	Pochavaram	KMM	52	B.Cotton	IRR	3,10	99	3.0 x 2.0	146.01	73.76	33.69
22.	Bhaskar Rao T	Pochavaram	KMM	40	B.Cotton	IRR	3,7,130	97	3.0 x 2.0	132.52	78.52	39.76
23.	Subba Raju G	Pochavaram	KMM	29	B.Cotton	IRR	3,7	99	3.0 x 2.0	67.31	43.31	

PKM – PRAKASHAM; KMM – KHAMMAM; NLR – NELLORE; GNT – GUNTUR; WG – WEST GODAVARI

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